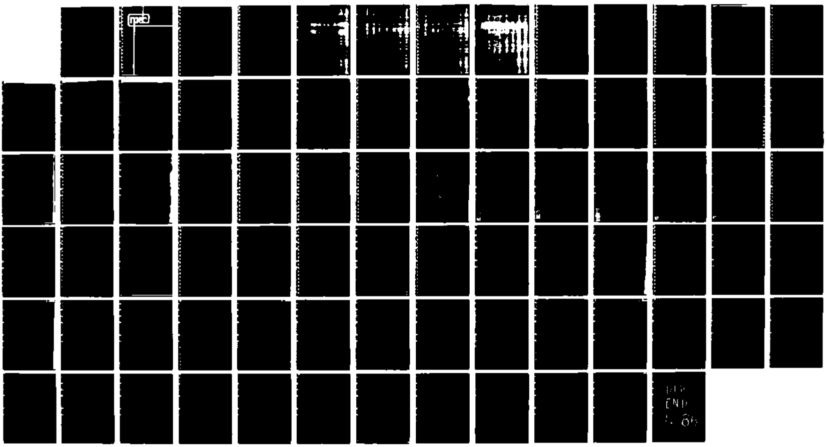
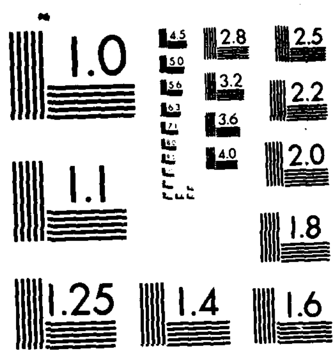
AD-A165 421 QUANTIFICATION OF TECHNICAL MANUAL GRAPHICS COMPREHENSIBILITY(U) NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO CA T E CURRAN ET AL. JAN 78 NPRDC-TN-78-2

1/1

UNCLASSIFIED F/G 5/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NPRDC TN 78-2

JANUARY 1978

QUANTIFICATION OF TECHNICAL MANUAL GRAPHICS COMPREHENSIBILITY

NPRDC TN 78-2 January 1978

QUANTIFICATION OF TECHNICAL MANUAL GRAPHICS COMPREHENSIBILITY

Thomas E. Curran

Michael Mecherikoff
EG&G Washington Analytical Services Center, Inc.
Hydrospace-Challenger Group

Reviewed by
Robert E. Blanchard

Navy Personnel Research and Development Center
San Diego, California 92152

FOREWORD

This work unit was performed in support of the Navy Technical Information Presentation Program (NTIPP) under the auspices of the Naval Ship Research and Development Center, Bethesda, Maryland. The goal of this program is to develop a system of procedures and equipments designed to support and improve the utility, preparation, revision, storage, distribution, and overall management of technical data for the mid-1980 time period. The Navy Personnel Research and Development Center was tasked with investigating a problem fundamental to this goal--the assessment of comprehensibility and usability of graphic materials in technical manuals. This is a preliminary report of findings in this investigation. It details initial guidelines pertinent to graphic comprehensibility and also provides an approach for exploring these critical issues further. A wider variety of Navy ratings and a broader range of experience levels are required to substantiate the generality of the findings. Data to satisfy these requirements are now being collected and will be integrated with the results contained in this report to form a more comprehensive future document.

NAVPERSRANDCEN conducted an extensive review of technical graphics to select appropriate stimulus materials for experimentation. This study was conceived and designed on the basis of that review. Assistance in study design, collection and analysis of data, and preparation of this report was provided under contract with EG&G Washington Analytical Services Center, Inc., Hydrospace-Challenger Group, with Dr. M. Mecherikoff as the contractor's Project Director. Dr. T. E. Curran of NAVPERSRANDCEN was the Principal Investigator for the project and the Technical Monitor for the contract.

J. J. CLARKIN

Commanding Officer

SUMMARY

Problem

Current graphic practices for technical manuals, as set forth in military specifications, standards, handbooks, and other publications, are rarely based on objective evidence that they improve utility and comprehensibility. Methods based on valid data are not currently available either for establishing requirements for procuring technical manuals or for objectively measuring the effectiveness of a particular illustration in supporting the job performance of technical personnel.

Objective

To begin development of empirically based guidelines and objective measurement techniques to increase the usability of illustrations in technical manuals, thereby reducing the arbitrariness of existing requirements and guidelines.

Approach

The general approach was:

1. To identify a limited set of features which can be hypothesized as facilitating or inhibiting the usability of illustrations.

2. To construct technical illustrations displaying variations of these features. and

3. To measure the performance of Navy technicians extracting selected information from the illustrations.

Specifically, part location and identification were the technician behaviors selected for study. They are common technician actions, the elements in drawings which support them (callouts and zones) are easy to identify and manipulate experimentally, and user performance can be defined objectively in terms of search time. A callout is any label or information on the drawing itself which identifies a part. Callouts usually consist of nomenclatures, reference designators, numbers keyed to text or tables, or a combination of these. Zones are areas of a drawing identified by alphanumeric coordinates in the manner of a road map. Examples of callouts and zones are shown in the figures of Appendix A.

Two drawings, a cross-sectional view and an exploded view, were used to present the stimulus variations to the subjects. These variations were:

1. 10, 27, 44, or 62 callouts per drawing.

2. Callouts with nomenclature, numbers, or both.

3. Number callouts in sequential or random order.

4. Number callouts circled for easier discrimination or not circled.

5. Number callouts located in straight lines for easier scanning versus placement close to the part identified.

The experimental tasks closely simulated actual use of the drawings. Subjects were required to locate a part given the callout number or nomenclature, to identify the part marked on the drawing, or to use the zone system to locate a part given the callout number or nomenclature. Tables listing parts in order of callout numbers were provided as needed.

Upon finding the required information, the subject made an overt response so that the search time could be measured accurately. Subjects were 144 Navy enlisted men in an electronic rating who were familiar with technical drawings.

Findings

1. For the task of finding a part given a callout number:

   a. For numbers in sequence, there was little difference in search time as the number of callouts increased.

   b. For numbers in random order, as the number of callouts increased from 10 to 62, search time increased by a factor of three or four.

   c. Nomenclature in the callout along with the number did not interfere with the search for a number.

2. For the task of finding a part given nomenclature (tables were in order of callout numbers rather than alphabetical by nomenclature):

   a. For 10 callouts, scanning nomenclature callouts was more efficient than using a table.

   b. When the number of callouts was larger (27 or greater), searching a table, even when not alphabetical, was superior to scanning callouts.

   c. As the number of callouts increased from 10 to 62, median search time increased by a factor of about six.

3. For the task of giving the nomenclature of a marked part (tables in callout number order are efficient for this task):

   a. There was a small increase in search time from 10 to 27 callouts and no increase beyond that.

   b. Where nomenclature was in the callouts, there were no differences due to increasing the number of callouts.

c. For 10 callouts, using a table was as efficient as having nomenclature in the callouts; for larger numbers of callouts, there was an advantage to having nomenclature in the callouts even when the number of callouts was large and the drawing appeared cluttered.

4. Circling callout numbers and lining them up for easy scanning yielded inconsistent results. An uncontrolled variable may have clouded the effects, but in any case the effects were weak compared to the sequence-random effect.

5. The use of zones was not tested thoroughly in this study. The results were inconsistent, but test items requiring use of zones invariably had longer search times than similar items not using zones.

6. Insofar as comparisons could be made, responses to the two drawings were very similar, leading to the hypothesis that cross-sectional drawings and exploded views are variations of a single "type" of drawing, at least with respect to usability requirements.

Conclusions

With regard to the part location and identification problem:

1. For part location by callout number, always arrange the callouts in numerical order.

2. For part location by nomenclature, use nomenclature callouts if the number of callouts is 10 or less; otherwise, use number callouts in sequence keyed to an alphabetical table.

3. For part identification (finding the nomenclature when the location is known), use nomenclature callouts even when the number of callouts is large and the drawing looks cluttered (there are no data on the upper limit).

4. If the numbers are in sequence, devices to enhance discriminability and visual scanning, such as circling and lining up the numbers, are probably unnecessary.

5. Zones are not useful for locating parts when a number callout must also be used for verification.

With regard to this study as a prototype, the basic approach of isolating information search behaviors and varying features of drawings which influence the search appears very promising.

Recommendations

1. Initiate changes to Navy technical manual procurement documents to conform to the conclusions of this study.

2. Pursue clarification of the graphic comprehensibility issue through empirical studies of the users' information search behavior and the stimulus variations that influence its effectiveness.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Problem

Since illustations may easily comprise 50 percent or more of a technical manual, the effectiveness of graphics in communicating technical information is critical. Current graphic practices, set forth in military specifications, standards, handbooks, and other publications, are rarely based on objective evidence that they improve utility and comprehensibility. Requirements in different documents sometimes contradict each other. Methods based on valid data are not currently available either for establishing requirements for procuring technical manuals or for objectively measuring the effectiveness of a particular illustration in supporting the job performance of technical personnel.

Objective

The objective of this research is to begin development of empirically based guidelines and objective measurement techniques to increase the usability of illustrations in technical manuals.

Specifically, the objectives of this study are:

1. To identify a limited set of features which can be hypothesized as facilitating or inhibiting the usability of illustrations.

2. To construct technical illustrations displaying variations of these features.

3. To measure the performance of Navy technicians extracting selected information from the illustrations.

By systematically varying a small number of well-defined features and objectively measuring the effect on specific tasks simulating actual use, the following goals can be achieved:

1. A quantitative index of effectiveness, such as time-to-locate-information, can be associated with variations of specific features, as a step towards a more generalized graphic comprehensibility metric in the future.

2. Requirements in specifications and guides can be made less arbitrary by basing them on performance data.

Background

This section describes the current status in the quantification of graphic comprehensibility, lists a number of assumptions or principles which guided the formulation of the research approach, and presents the rationale for the specific focus of the present study.

Current Status

In a recent comprehensive survey of technical manual comprehensibility, Curran[1] concluded that ". . . little is known of the variables making up illustrations of various kinds and their relationship to the comprehensibility of that illustration. The guidance which is offered technical illustrators is for the most part intuitive; virtually no empirical evidence is available."

There have, of course, been serious efforts to control characteristics of artwork in technical manuals specifically for the purpose of facilitating the transfer of information to the user. At least two major approaches can be cited.

The first approach is to implement an entire philosophy of how technical information is best presented. This is done through a set of procurement documents detailing the characteristics of the manual and often the processes by which the product is to be achieved. Examples are the Functionally Oriented Maintenance Manuals (FOMM), Fully Proceduralized Job Performance Aids (FPJPA), NAVAIR's Work Package concept, and the Army's Integrated Technical Documentation and Training (ITDT) program. Artwork requirements, often quite detailed, are developed on the basis of general experience, opinion, aesthetic considerations, past practice, reactions against past practice, and reasoning from the overall philosophy. Once the requirements are set forth in procurement documents, technical manuals are procured in conformance with them, and it is nearly impossible to investigate the impact on user performance of systematically varying the more arbitrary aspects of the requirements.

The second approach is represented by several recent studies aiming to relate personnel characteristics such as test scores, rating, reading ability, and experience level, together with characteristics of the task and the work environment, to optimum data presentation modes and formats. Recent work in this vein sponsored by the Navy Technical Information Presentation Program (NTIPP) provides the beginnings of a model by which the best type of graphic presentation can be selected for a given set of personnel, task, and environmental factors. This approach thus far has been solely concerned with choice of overall type of format, and having recommended, for example, an exploded view of an assembly, makes no recommendations about features of the drawing itself which may make it easy or difficult to use.

These are both positive and important approaches, in that they focus on tailoring technical information to match the user's characteristics, needs, and work environment. However, the present NTIPP-sponsored study is believed to be the first to employ the type of detailed analysis and objective validation needed to address the problem stated at the outset.

---

[1] Curran, T. E. Survey of Technical Manual Readability and Comprehensibility (Tech. Rep. 77-37). San Diego: Navy Personnel Research and Development Center, June 1977. (NTIS No. AD-A042 335)

A great deal of technical artwork is controlled by MIL-STD-100 (Engineering Drawing Practices). For economic reasons, it is encouraged that engineering drawings be used or adapted for use in technical manuals, since removing extraneous material from existing drawings is less costly than producing new artwork expressly for the maintainer or operator. Because of a lack of the type of research represented by the present study, it is not clear that drawings designed to meet the needs of designers and builders are optimal for maintainers and operators, or to what degree and in what ways they are suboptimal. Casual examination of engineering drawings suggests several ways in which such drawings might be improved for maintainer or operator use. Without empirical data on the effects of using current engineering drawing practices to produce artwork to support Navy technican performance, it is impossible to estimate long run cost/benefit ratios as an alternative to immediate cost savings in artwork production.

Guiding Assumptions

To provide an orientation for the development of specific studies of the interaction between a user and his graphically presented data, the following principles or assumptions were formulated:

1. At a particular point in his overall sequence of behavior as a maintainer or operator, the user has need of information which is graphically presented. At that point he turns to the graphic presentation, having certain prior information which is his starting point to find what he needs. Based on what he already knows (entry information), he engages in a search, which may be long or short, for what he needs (target information).

2. Certain identifiable characteristics of arrangement, labeling, referencing, drawing practices, and so forth can influence the effectiveness of his search. The particular combination of factors contributing to an effective search will depend on the entry information and the target information. Graphic presentations designed for one type of search will not necessarily be most effective for another type.

3. In some cases, the beginning and end points of the information search are relatively easy to identify. Early research should focus on such cases, both to generate knowledge about them and to provide insights into methodology for less obvious and more complex user activities.

4. The user himself is generally not aware of the details of his data extraction process or of the factors which optimize or degrade it. His opinion about good and bad artwork can suggest clues for further investigation, but only direct performance measurement should be considered conclusive. The user may become aware of the search process if it becomes unusually difficult or time consuming, but even then it may not be obvious to him what would improve the presentation. The user's attention is not focused on the data extraction process itself, nor should it be: an effective search for data will be as short, automatic, and nonintrusive as possible.

5. It is not always obvious to an illustrator what the optimal combination of characteristics is, even when the illustrator is aware of the search chain from entry information to target information, and often he is not aware of it or does not consider it.

6. Aesthetic considerations alone will not guarantee optimal usability and may sometimes result in degrading usability. That is, it may be necessary to violate aesthetic principles (for example, clean appearance) in order to optimize information search.

7. Comprehensibility or usability of a graphic presentation is not a property of the graphic presentation per se, but depends on what information is being sought from it at a particular moment. It reflects a relationship between the characteristics of the graphic presentation and the task being performed at that moment. Therefore, an index of usability or comprehensibility that does not take the intended use into account is seriously deficient.

Definition of a Specific Problem for Study

Two important assumptions are that the use to which an illustration is to be put is critical in evaluating its usefulness, and that the evaluation must be made in terms of measures of user performance. Because of these, certain very interesting types of graphics are almost automatically excluded for the present. For example, complex, cognitive tasks (e.g., troubleshooting) and the illustrations which support them (e.g., schematics and block diagrams) were not considered amenable at this time to a fine-grained objective study. It is expected that the type of research represented by the present study will suggest ways of objectively studying these other important graphic types and the behaviors associated with them.

Location and identification of parts, however, were judged to be highly suitable user activities for the present study for the following reasons:

1. They are common activities among technical manual users.

2. They are supported by a number of different types of pictorial drawings, such as isometric drawings, cross-sectional views, exploded views, circuit board drawings, and control panel drawings.

3. Elements of the drawings which are intended to support this type of search, such as callouts and zones, are obvious. Varying these elements for experimental purposes is not difficult.

4. Advice and requirements relating to these elements are not always consistent, and sometimes appear to derive from considerations of aesthetics and contractor convenience rather than effectiveness and user convenience.

5. Examples of what appear to be violations of human factors considerations and even common sense are not difficult to find in recently published technical manuals.

6. The user's information search task can be easily and realistically simulated with experimental controls.

Having limited the present study to part location and identification, the scope of questions which might be asked is still very broad. These include:

1. Should number callouts be in sequence? What price in efficiency is paid if they are not? Are there cases where numerical sequence is unimportant?

2. What is the maximum number of callouts that should appear on a drawing? Do number callouts and nomenclature callouts differ in this respect?

3. What is the tradeoff between having nomenclature callouts on the drawing versus putting the nomenclature in a table keyed to number callouts?

4. When reference designators are used as callouts, are they less discriminable than nomenclature or numbers, and therefore harder for a user to find quickly and accurately?

5. Do graphic devices, such as circling the numbers or using large, bold type, help the user scan more effectively?

6. Should leaders (the line connecting the callout to the part) or arrows be short so that the callout is close to the part it identifies, or is scanning aided if the leaders are extended so the callouts are arranged in straight lines?

7. If alphanumeric zones are used, what size of zone is most effective?

8. Should the zone reference identify the location of the center of the part, the callout, or the arrowhead?

9. Zone designators on engineering drawings use the lower right corner as the origin and run backwards from the normal reading direction (right to left and bottom to top); does this degrade search performance?

There are, of course, additional questions concerning the interaction of the various factors with each other and with the type of search being performed. Some of the above questions were addressed in part in the present study. Because of the need to limit the scope of the present study, reference designators were not studied, and zones were represented only minimally to collect information for the design of a future study.

Three common types of information search related to part location and identification were simulated in the study:

1. A part is cited by callout number in a procedure, explanation, or description: find the part in the drawing.

2. A part is cited by nomenclature in a procedure, explanation, or description: find the part in the drawing.

3. A part location in a drawing is known (for instance, by recognizing its physical appearance): find its nomenclature.

METHOD

The general approach was to identify tasks which closely simulate what a technician does when he is using a graphic presentation to get needed information. In this study the tasks were restricted to location and identification of parts, using callouts with and without parts lists, and, to a minor extent, using zones. As described below, variations in number, content, and arrangement of callouts were incorporated into drawings, were presented to subjects using five different types of task instructions, and were evaluated according to the time required for the specified information search.

Illustration Types

Stimulus variations were incorporated into two basic drawings taken from Navy technical manuals: a cross-sectional (C/S) view of an electric motor, and an exploded view (E/V) of a chart drive. These drawings are typical of drawings found in virtually all types of Navy technical manuals. The originals of these two drawings were modified to produce the experimental variations, examples of which are reproduced in Appendix A. All the types of variation are illustrated in these examples. The original drawings appear as Figures A-2 and A-6, except that A-2 was hand lettered in its original form.

Variations of the cross-sectional view are not directly comparable to those of the exploded view. In particular, the cross-sectional view as originally drawn had nomenclature callouts, which were retained in some of the variations. Because of the placement of callouts on the exploded view, nomenclature callouts were completely impractical.

Number of Callouts

The number of callouts on a drawing was varied in four steps: 10, 27, 44, and 62. This variable was applied in identical fashion to both the cross-sectional view and the exploded view.

Content and Arrangement of Callouts

There were 13 variations in the content and arrangement of callouts. Five of these were applied to the cross-sectional view:

1. Nomenclature only (NOMEN).

2. Numbers in sequence (NUM-SEQ).

3. Numbers in random order (NUM-RAN).

4. Nomenclature with numbers in sequence (N/N-SEQ).

5. Nomenclature with numbers in random order (N/N-RAN).

Table 1

Description of Subject Tasks

Task	Instruction	Typical Simulated Situation
1	"Point to the part with callout number X.	Callout number appears in a procedure or equipment description referencing a figure.
2	"Point to the part called Y."	Nomenclature appears in a procedure or description referencing a figure.
3	"Tell me the nomenclature of the part marked in red."	Physical appearance of the part is known, and the nomenclature is sought.
4	"Use the zone system to point to the part with callout number X."	Same as task 1.
5	"Use the zone system to point to the part called Y."	Same as task 2.

with callout number 28. Go." The subject would then turn to the drawing and find the required part.

Selection of Target Information

For each test item, a part was selected, the location or identity of which was the target of the information search. Targets were selected with three primary criteria:

1. Responding to a test item should not aid the subject on a later item.

2. Targets were selected equally from all areas of the drawings.

3. Items differing only by number of callouts were assigned targets which were not identical but which, to the extent possible, were in the same area of the drawing.

Table 2

Summary of Independent Variable Definitions

Subject task	Definition
1	Point to part given callout number
2	Point to part given nomenclature
3	Tell nomenclature of marked part
4	Use zone system to point to part given callout number
5	Use zone system to point to part given nomenclature

Number of callouts
10
27
44
62

Content and arrangement variation	Type of drawing	Definition
NOMEN	C/S[a]	Nomenclature only
NUM-SEQ	C/S	Numbers only in sequential order
NUM-RAN	C/S	Numbers only in random order
N/N-SEQ	C/S	Nomenclatures with numbers in sequential order
N/N-RAN	C/S	Nomenclatures with numbers in random order
SEQ/C/E	E/V[b]	Sequential, circled, extended
SEQ/C/NE	E/V	Sequential, circled, not extended
SEQ/NC/E	E/V	Sequential, not circled, extended
SEQ/NC/NE	E/V	Sequential, not circled, not extended
RAN/C/E	E/V	Random, circled, extended
RAN/C/NE	E/V	Random, circled, not extended
RAN/NC/E	E/V	Random, not circled, extended
RAN/NC/NE	E/V	Random, not circled, not extended

[a] Cross-sectional view. Callouts are not extended to edge and numbers are circled.

[b] Exploded view. Callouts have numbers only. They may be circled or not circled, and extended to edge or not extended.

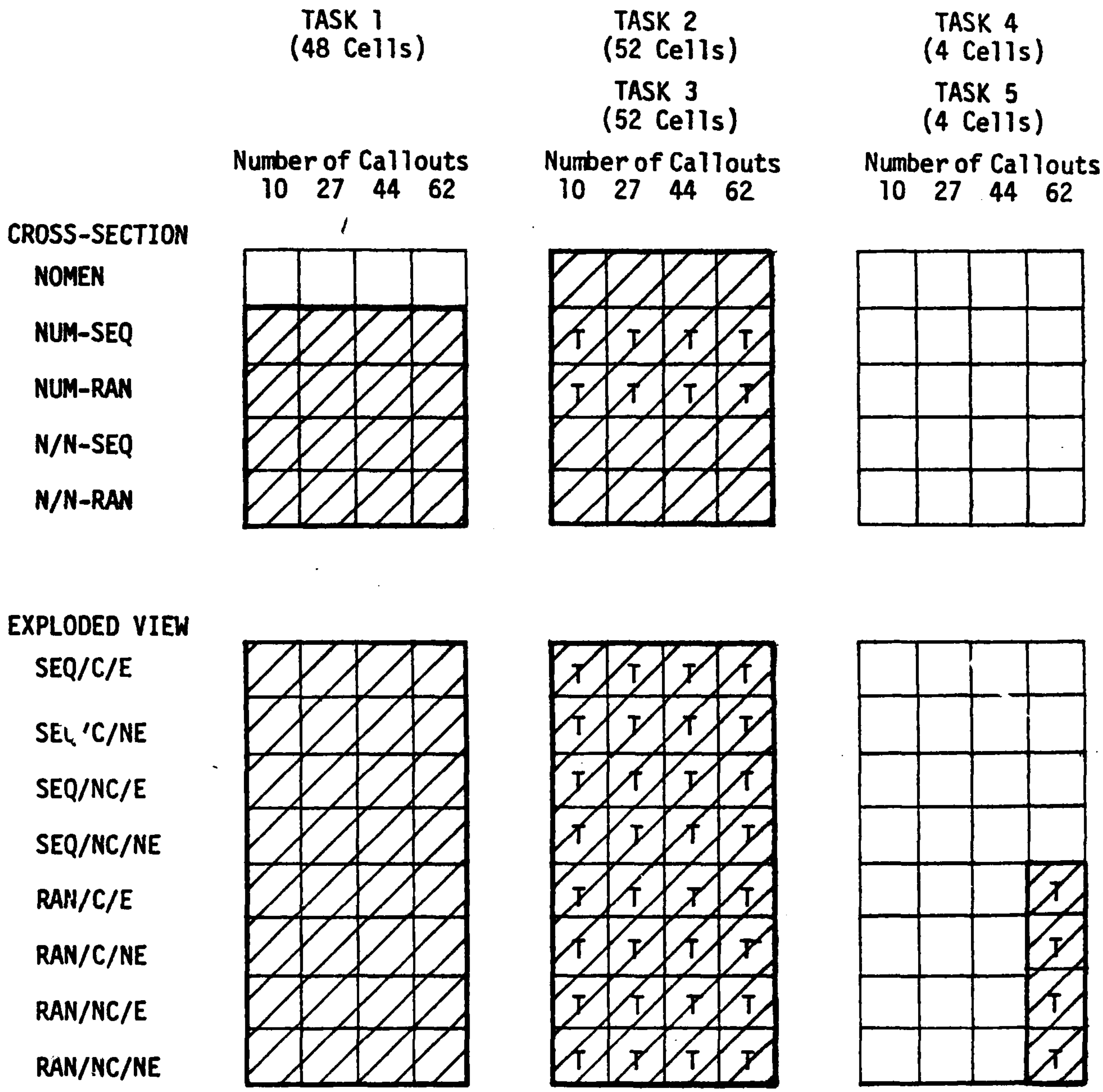


Figure 1. **Diagram of experimental design: stimulus-task combinations used in study are cross-hatched; T indicates use of parts list table required. See Table 2 for detailed definitions.**

Accompanying Tables

In Tasks 2, 3, 4, and 5, the subject often required information which was not part of the callout. Tables (parts lists) were used to supply the missing information. In Tasks 2 and 3, the table provided the bridge between callout number and nomenclature, and in Tasks 4 and 5, the table provided zone information. All tables were in the same format. The number of items in the table corresponded to the number of callouts on the drawing. The items were listed in callout number sequence. The result was that the tables were efficient when entered by callout number, and less efficient when entered by nomenclature. No task required the subject to enter the table by zone designation. Test items which required the use of a table are indicated in Figure 1.

Groups

Preliminary trials using the stimulus materials indicated that to administer all 160 test items to one subject would have made the subject's task excessively long. Therefore, the 160 test items were divided into four groups of 40 each, such that the various levels of each independent variable were represented equally in each group. One group of 40 test items was administered to each subject.

Other Materials

In addition to the drawings for each group, which were bound in scrambled order for the subjects' use, there was a corresponding set of item description sheets to be read to the subjects in connection with each drawing. Prior to administration of the test items, each subject filled out a data sheet soliciting rate, educational level, Navy schools attended, and extent of shipboard experience. Standard explanations and instructions were read to the subjects. Since the experimenter's task was extremely tedious, all materials were organized for easy, error-free administration.

Dependent Variable

The response variable was the time in seconds (recorded to the nearest tenth) required to complete each information search. After reading the item description sheet, the experimenter said, "Go," whereupon the subject turned to the next drawing and the timing began. Timing continued until the subject either pointed at a part in the drawing or began to speak his response, as required. If the response was not correct, as happened occasionally, the experimenter said, "That's not it," and resumed the timing.

Subjects

Subjects for this study were 144 Navy enlisted men in an electronic rating. All subjects had training in intermediate electronics and 93 percent had advanced (C-school) training. Most (61 percent) had shipboard experience maintaining or operating complex electronic gear. Distribution of the sample by rate is as follows:

Chief Petty Officer	1.4%
Petty Officer First Class	12.8%
Petty Officer Second Class	33.3%
Petty Officer Third Class	45.1%
Seaman	8.3%

Subjects were well-motivated and cooperative. Based on spontaneous comments by subjects, the stimulus variations were obvious enough that the subjects could see potential practical outcomes of the study related to their job tasks.

Data Analysis

Selection of an approach to data analysis must take into account the following considerations:

1. A cursory examination of the data indicated that the distributions are very markedly skewed, as would be expected of time data of this sort.

2. Means and variances of the distributions appear to be correlated to a substantial degree.

3. Because the cells of the design are divided among four groups of subjects, the observations may not be statistically independent.

4. It is necessary to make numerous tests of significance on the data, pooling observations from the same subjects and from different subjects in various combinations.

Under these circumstances, the following was regarded as the most reasonable approach:

1. Use appropriate nonparametric tests. There is evidence that the correlations among observations are negligible; the use of nonparametric tests appears justified. The Mann-Whitney U test for the two-sample case and the Kruskal-Wallis test for the k-sample case were selected because they are the most powerful nonparametric tests of their respective null-hypotheses.

2. Recognize the need to be conservative in selecting a significance level. When numerous tests are performed, it is expected that some of the "significant" differences will actually be due to chance. This is less likely if the significance level is conservative. Consider using $p < .001$ as the lowest acceptable level.

3. Recognize that the tests are not strictly tests of central tendency differences but "bulk of the distribution" differences. That is, they measure the extent to which the scores of each distribution exceed scores of the other distribution(s). However, since the distributions are all skewed similarly, the tests in most cases can be reasonably viewed as central tendency tests.

RESULTS AND DISCUSSION

Test Item Distributions

Appendix B contains descriptive data on the distribution of scores for each of the 160 test items. Specifically, the tables in this appendix show the highest and lowest scores, the quartiles, the range, the interquartile range, the number of subjects, and the subject group to which the item was administered. These distributions are displayed in groups of four. For Tasks 1, 2, and 3, the distributions for the four number-of-callout steps are shown together; thus one can directly see the effect of increasing the number of callouts. For Tasks 4 and 5, there were only four test items administered; these are shown together (Tables B-39 and B-40). For each set of four test items, the result of the Kruskal-Wallis k-sample test is shown. Numerous other significance tests were performed and are cited in the text as appropriate.

In general, a large proportion of the Kruskal-Wallis and Mann-Whitney tests performed indicated highly significant distribution differences among the various conditions. Since most of the significant differences were in the expected direction and were well beyond the .001 level, it appears reasonable to accept this as evidence that the factors which were varied in fact influenced performance (search time).

Cross-Sectional View

In Task 1, the instruction to the subject was to point to the part with a given callout number. When the numbers are in sequence, there is generally only a small increase in the search time as the number of callouts increases. No consistent difference emerges attributable to the potentially confusing presence of nomenclature on the drawing (tests of significance gave mixed results). When the callout numbers are in random order, there again seems to be little difference due to the presence of nomenclatures. However, the search time does tend to increase as the number of callouts increases. One could say with reasonable safety that it takes approximately three to four times as long to find a part on the drawing when there are 62 callouts as when there are 10 callouts.

In Task 2, in which the subject was to point to the part given the name of the part, nomenclature in callouts is being compared with the same nomenclature listed in an accompanying table. It will be recalled that the ordering of the nomenclatures in the table is by callout number, so that the search for a given part name, both on the drawing and in the table, was not assisted by alphabetical order or any other systematic feature of the part name. The results suggest the following interpretations:

1. In the 10-callout conditions, the scanning of the callouts is sufficiently simple that it is superior to the use of the table and subsequent linking by callout number; the difference between random and sequential order in this case is negligible.

2. As the number of callouts increases, the search time also increases. For the conditions using nomenclature in the callouts, the median search time increases by almost a factor of six between 10 callouts and 62 callouts.

3. For the conditions in which the use of a table is required, the analysis is slightly more complex. The subject must first locate the name in a table and note the callout number, and then use the callout number to locate the part in the drawing. When the callout numbers are in sequence, most of the increase in search time can be attributed to searching the table. When the callout numbers are in random order, the time spent locating the callout becomes significant. Therefore, although both of these conditions show an increase in search time with an increased number of callouts, the condition with random callout numbers shows a greater increase in search time, as would be expected. Considering the case of 62 callouts, putting the callouts in numerical sequence cuts the search time nearly in half. Still considering the case of 62 callouts, it may be noted that neither condition in which the nomenclature was in the callouts was superior to the condition in which a table was used and the callout numbers were in sequence. This suggests that when the number of callouts is large, searching a table, even when the table is not in alphabetical order, is more efficient than searching through the callouts. This is the reverse of the situation when the number of callouts is small. Using alphabetical tables might bring the search time down as low as 5 seconds even for drawings with a large number of callouts.

Task 3 responses are those in which the subject was to tell the name of a part marked in red. Again, tables were necessary for some conditions. For these, the subject found the callout number from the drawing and used that number to enter the table. Since the tables were organized according to callout number sequence, the tables were efficiently designed for this type of response, and the times are relatively short. There appears to be some increase in search time as the number of callouts increases from 10 to 27, but not much difference for subsequent increases in number of callouts. For the conditions in which the nomenclature was contained in the callouts, there were no differences clearly attributable to increased number of callouts, and no differences were expected. In the case of 10 callouts, there was no difference between having the nomenclature in the callouts or using a separate table; for larger numbers of callouts, there appears to be an advantage to having the nomenclature in the callouts, even when the number of callouts is large.

Exploded View

The results with respect to random versus sequential order of callouts were very conclusive, while circling, extending leaders, and using zones produced mixed, inconclusive results.

Random (RAN) and Sequential (SEQ) Order

As expected, the order of the number callouts was the most powerful variable manipulated in this study. For Tasks 1, 2, and 3, within each number-of-callouts step, the SEQ conditions were combined and contrasted with the RAN conditions. The results are shown in Table 3 and in Figure 2. In Task 1, the numbers are used to locate parts without a table. In Task 2, they are used with a table, which accounts for the increase in search time. When the time required to search the table is subtracted out of these data, the Task 2 SEQ curve collapses to approximate the Task 1 SEQ curve, in which no table is used. In all four number-of-callout steps in Tasks 1 and 2, the difference between the RAN and SEQ conditions is highly significant. The magnitude of the difference is small for 10 and 27 callouts, but with a large number of callouts, putting the numbers in sequence can reduce the search time by a factor of three.

Table 3

Medians of Sequence versus Random Conditions for Exploded View for Tasks 1, 2, and 3

Conditions	Number of Callouts			
	10	27	44	62
Task 1				
SEQ	2.00	2.50	2.15	2.10
RAN	2.55	3.55	6.80	7.65
p	.001	.001	.001	.001
Task 2				
SEQ	4.10	7.00	6.25	11.10
RAN	5.00	9.10	17.60	17.50
p	.001	.001	.001	.001
Task 3				
SEQ	2.80	3.20	3.20	4.00
RAN	2.40	3.05	3.35	3.35
p	.01	.01	.01	.01

Note. The p values indicated were obtained by comparing the SEQ distribution with the RAN distribution using the Mann-Whitney U test.

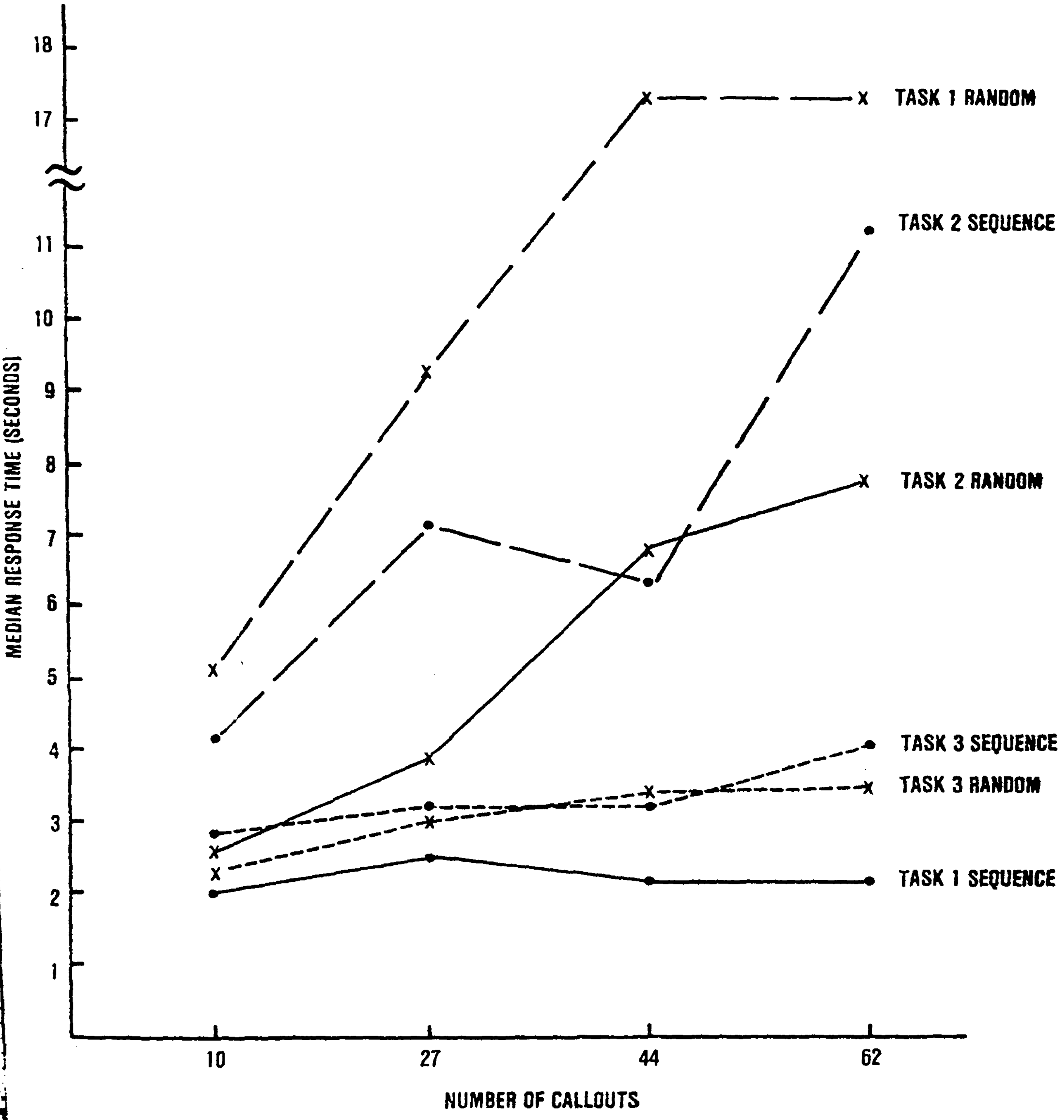


Figure 2. Medians of Sequence Versus Random Conditions for Exploded View for Tasks 1, 2 and 3.

Task 3 did not require a search for numbers on the drawings, and the tables were arranged in callout number sequence. Therefore, significant differences were not expected, since the order of the numbers made no difference in performing the task. For 44 and 62 callouts, the differences were not significant even at the .05 level, although the number of observations was large. For 10 and 27 callouts, the differences were moderately significant, but they favored the random arrangement. The reason for this result is unknown.

The conclusion to be reached is that there is a performance advantage to using numbers in sequence rather than in random order for tasks requiring the user to search for a number. The advantage is small when the number of callouts is small, but becomes appreciable for drawings with large numbers of callouts.

Circling Callouts and Extending Leaders

Circling number callouts and extending leaders to enhance visual scanning were expected to be much weaker in their effects than the sequence-random variable. In fact, it was anticipated that, if the numbers were in sequence, hardly anything else would matter. Therefore, the C and E variables would prove beneficial only when the numbers were in random order and when there were many callouts to scan. The random conditions for 44 and 62 callouts, Tasks 1 and 2, were examined, and the results were mixed and inconsistent.

There are thought to be two major causes for these unsystematic findings:

1. the position of the target information in the table (for Task 2 only), with resulting differential table search times, and

2. a systematic perceptual phenomenon (for example, a figure-ground effect or a generalized scanning strategy) which so far is unexplained.

On the basis of a small study of table search times, it appears that the first of these factors accounts almost entirely for the increasing slope of the Task 2 SEQ curve in Figure 2. As the number of callouts increases from 10 to 62, more time on the average is required to search the longer tables. This factor also operates in the Task 2 RAN condition, but seems much less powerful than the randomness itself.

The second factor, on the other hand, contributes much more variance to the random conditions than to the sequence conditions. Its effect is to make the perception of information on the drawing more or less difficult depending upon where the information is located. Scanning numbers in sequence is only minimally affected by the phenomenon, if at all, but finding a specific number in a random grouping is seriously affected.

The effects of these two factors were particularly evident in the comparisons among the four circling and extending conditions. For instance, in Table B-18, the 62-callout scores seem excessively high, and in Table B-20, the 62-callout scores appear to be overly low. The bulk of the inconsistency in each case is explainable by the position of the target item in the tables. In Table B-24, representing a random condition, the 44-callout scores were considerably higher than those for 62 callouts. In this case, examination of the stimulus materials suggests that target location on the drawing caused the reversal.

In summary, while comparisons among the circle/extend conditions cannot be made with confidence, the overall data indicate that circling callout numbers and extending leaders are at best weak variables, even when the number of callouts is large.

Zones

The tasks performed by the subjects in this study did not lend themselves to the use of zones. The subjects frequently seemed confused on these test items and the results are not enlightening. Comparing the Task 4 and 5 items with their corresponding Task 1 and 2 items, the items with zones invariably had longer search times. Zones are not useful for locating parts when a number callout must also be used for verification.

The Task 4 distributions were not significantly different from each other. In Task 5, the C/E cell was significantly lower than the others, which would be reasonable except for the fact that the overall data on circling and extending leaders makes this finding suspect.

Cross-Sectional versus Exploded Views

The NUM-SEQ and NUM-RAN conditions of the cross-sectional drawing were similar to the exploded view drawings in that they had no nomenclature. This allowed a comparison between responses to the two drawings. For each number-of-callouts step, a comparison was made between NUM-SEQ and the combined SEQ conditions for the exploded view, and between NUM-RAN and the combined RAN conditions for the exploded view. Of the 24 comparisons, 11 were not significant at the .05 level and 5 were significant at the .001 level. Of these five, four indicated somewhat longer times for the cross-sectional view. The conclusion is that responses to the two drawings were for the most part very similar; either type of drawing could be used in this type of study. There were some obviously confusing elements in this particular cross-sectional drawing which probably accounted for the significant differences.

Independence of Observations

A factor which could generate an excess of significant sample differences where no differences really exist is the possibility of correlated observations. Such correlations might exist because the same subjects were used for groups of test items. Thus, if speed of response is a subject trait, and one of the groups of subjects happened to have a large proportion of fast subjects, this would be reflected in conditions scattered throughout the experiment, causing "significant" differences not because of the stimulus (cell) characteristics, but because of the group (subject) characteristics.

It was impractical because of the number of scores to directly compare the four group distributions with a Kruskal-Wallis test, and the meaning of the results would be obscure since the effects of the experimental factors would be influencing the scores of the four groups unequally. Nevertheless, a satisfactory analysis is possible.

If search speed is not a subject trait, but is instead associated with test items, then the observations can be considered essentially independent for the purpose of further analysis. Three analyses were performed using the Kendall Coefficient of Concordance (W) method to calculate average Spearman rank difference correlations (rho).

The first analysis may be thought of as pairing the 36 subjects in each group to yield all possible pairs, calculating the rank difference correlation (rho) across the 40 test items, and finding the average rho of the 630 pairs. The average correlations turned out as follows:

Group	Average Rho
A	.74
B	.70
C	.73
D	.71

These average correlations are significantly different from zero well beyond the .001 level.

The interpretation of such a substantial average correlation is that the subjects reacted to the items similarly. Items with short times for one subject tended to have short times for the others. There were "hard" items and "easy" items; response time is definitely related to the test item. This finding agrees with a cursory examination of the item distributions, but also indicates the extent of the relationship. The close agreement between groups is one indication that the groups were equivalent.

The second analysis was similar, except that the test items were taken pairwise, with the correlations calculated across subjects. In this case, a high average correlation would mean that subjects are individually consistent; that is, there are fast subjects and slow subjects. Low correlations would indicate that subject responses tended to be independent of the subject; there is very little carryover from one test item to another.

Group	Average Rho
A	.16
B	.13
C	.17
D	.14

These correlations are also significant beyond the .001 level, but are uniformly low, indicating almost no relationship between test items.

Taken together, these results indicate that it is justifiable to regard all the scores as essentially independent measures reflecting stimulus characteristics.

A third analysis confirmed the second. Because of the way the items were assigned to groups, certain similar items were administered to the same subjects. In particular, there were 10 pairs of Task 1 items of this type, in which the two items in the pair differed only in having 27 callouts or 62 callouts. The correlation was calculated for each of the 10 items, yielding rhos ranging from -.08 to .33. They are uniformly low, and the highest fails to meet the .05 level of significance. This is further indication of the independence of the observations.

Value of the Results

This discussion will deal briefly with three questions which may be raised about this investigation:

1. Aren't the results intuitively obvious?

2. Will the results generalize to the work environment?

3. Even the longest search times are quite short; will these proposed guidelines really make much difference?

The major results--that numbers are easier to find if they are in sequence, that tables should be organized alphabeticaly or numerically depending on the user's entry information, and that drawings should be different for different uses--seem rational and obvious. The importance of this study is twofold: first, it provides an objective, numerical measure of the cost of violating these rational principles; second, the guidance and requirements found in current military procurement documents do not conform to the results of this study.

As to the generalizability of the findings, it should be noted that the subjects' task in the experiment was not truly a simulation of a job task, but rather a fractional part of it. In important respects the situation was quite real. The search times obtained in the study are probably underestimates of on-the-job times, however. The subjects were highly motivated to "beat the clock" in spite of instructions to relax and pace themselves "normally." Ordinary distractions and discomforts of the work environment were absent, and subjects' whole attention was on the graphic task. It is probable that in the work environment the same relative magnitudes or ratios would appear, but the actual search times would be longer.

Finally, even though the time for each individual information search is short, these are small tasks that occur with great frequency, so the total time could be appreciable. There is also an annoyance factor which was observed but not measured or recorded during the data collection. Subjects who had trouble finding a number or nomenclature sometimes became quite agitated. On the job, if the use of a drawing appears to make the job longer instead of shorter, harder instead of easier, the technician may reject the use of the drawings or the entire manual whenever he can get away with it. There is evidence that technicians do not use a manual when it appears harder to use it than not to. Every effort should be made to make the data in technical manuals as accessible to the user as possible.

Evaluation of the Study

The purpose of this study was not only to generate data on which to base guidelines, but to evaluate the feasibility of attempting an objective assessment of graphic comprehensibility or usability. As a prototype for future investigations, the study represents an approach which appears to have excellent possibilities for solidifying comprehensibility requirements in technical manual procurement documents. Insofar as the approach is new, it is because it focuses directly on the behavior of the technician as he attempts to extract needed data from a drawing. It does not attempt a theoretical formulation of graphic comprehensibility, nor does it attempt to operationally define stimulus features such as "density" and "clutter." It asks what the technician is doing with the drawing, and what factors might be influencing what he is doing. This method has the virtue of generating empirical relationships which should have direct application and hopefully will also provide a basis for theoretical developments regarding perception and human information processing in complex environments.

The most serious shortcoming in this study was the failure to control adequately for the two sources of extraneous variation: the location of the targets on the drawings and the position of the information in the accompanying tables. It is apparent that the impact of target location, both on the illustration and in the table, was greatly underestimated. It is hypothesized that systematic perceptual variations caused some target items to take much longer to locate than others (notably in the random conditions) and confounded certain of the results. Table search time, of course, is part of the total performance time, but based on data dealing with table search time only, this effect can be dealt with mathematically.

Overall, the practical impact of these factors is considered to be limited. The sequence-random effect was very strong, and leads to the conclusion that callouts should be arranged in sequence at all times. The hypothesized perceptual phenomenon is a problem only in the random conditions, which the results of this study suggest should never be used. It poses, at this time, an interesting theoretical question but not a practical one.

CONCLUSIONS

Part Location and Identification Problem

1. For part location by callout number, always arrange the callouts in numerical sequence on the drawing. This is most likely the best guideline even when the number of callouts is very small. It is preferable to have the callouts in sequence rather than to have them correspond to the numbering of procedural steps, if this results in their being out of order. If the numbers are in sequence, the number of callouts may be quite large, certainly greater than the 62 callouts used in this study.

2. For part location by nomenclature, if the number of callouts is 10 or less, nomenclature callouts may be used. Otherwise, an alphabetical table should be provided to key the nomenclatures to number callouts, which should be in sequential order on the drawing.

3. For part identification (finding the nomenclature when the location is known), nomenclature callouts are superior to numbers keyed to a table even when the number of callouts is so large that the drawing appears excessively cluttered.

4. If the numbers are in sequence, devices to enhance discriminability and visual scanning of number callouts, such as circling the numbers and lining them up, are probably unnecessary.

5. Zones are not useful for locating parts when a number callout must also be used for verification.

6. Since the guidelines differ depending on the type of information search, the drawing must be designed with the information search task in mind.

Research Approach

The approach represented by this study--isolating the technical manual users' information search behaviors and varying features of drawings which influence the speed and accuracy of his search--appears very promising. Care must be taken in future studies to randomize, counterbalance, or measure the effect of target location in the stimulus materials. Inadequate control of this in the present study caused confounding in certain desired comparisons, but need not cause problems in future applications of the approach.

RECOMMENDATIONS

1. Initiate changes to Navy technical manual procurement documents to conform to the conclusions of this study.

2. Pursue clarification of the graphic comprehensibility issue through empirical studies of the users' information search behavior and the stimulus variations that influence its effectiveness.

APPENDIX A

SAMPLES OF DRAWINGS SHOWING EXPERIMENTAL VARIATIONS

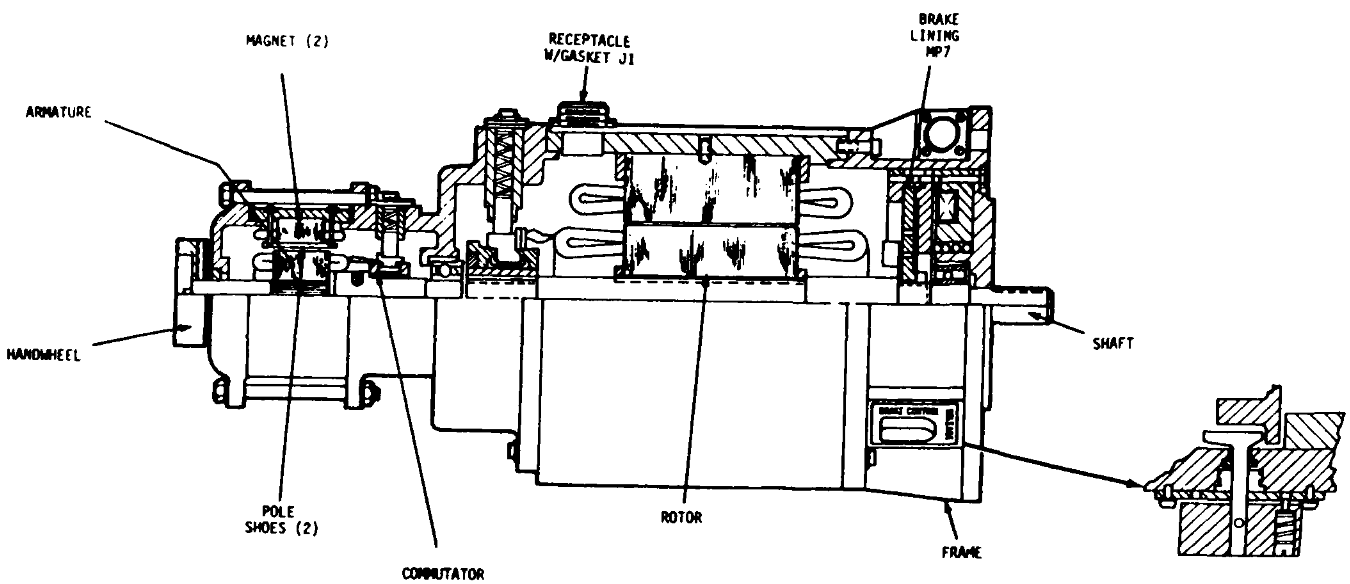


Figure A-1. Cross-sectional view, Case 1, Condition 1 (NOMEN).

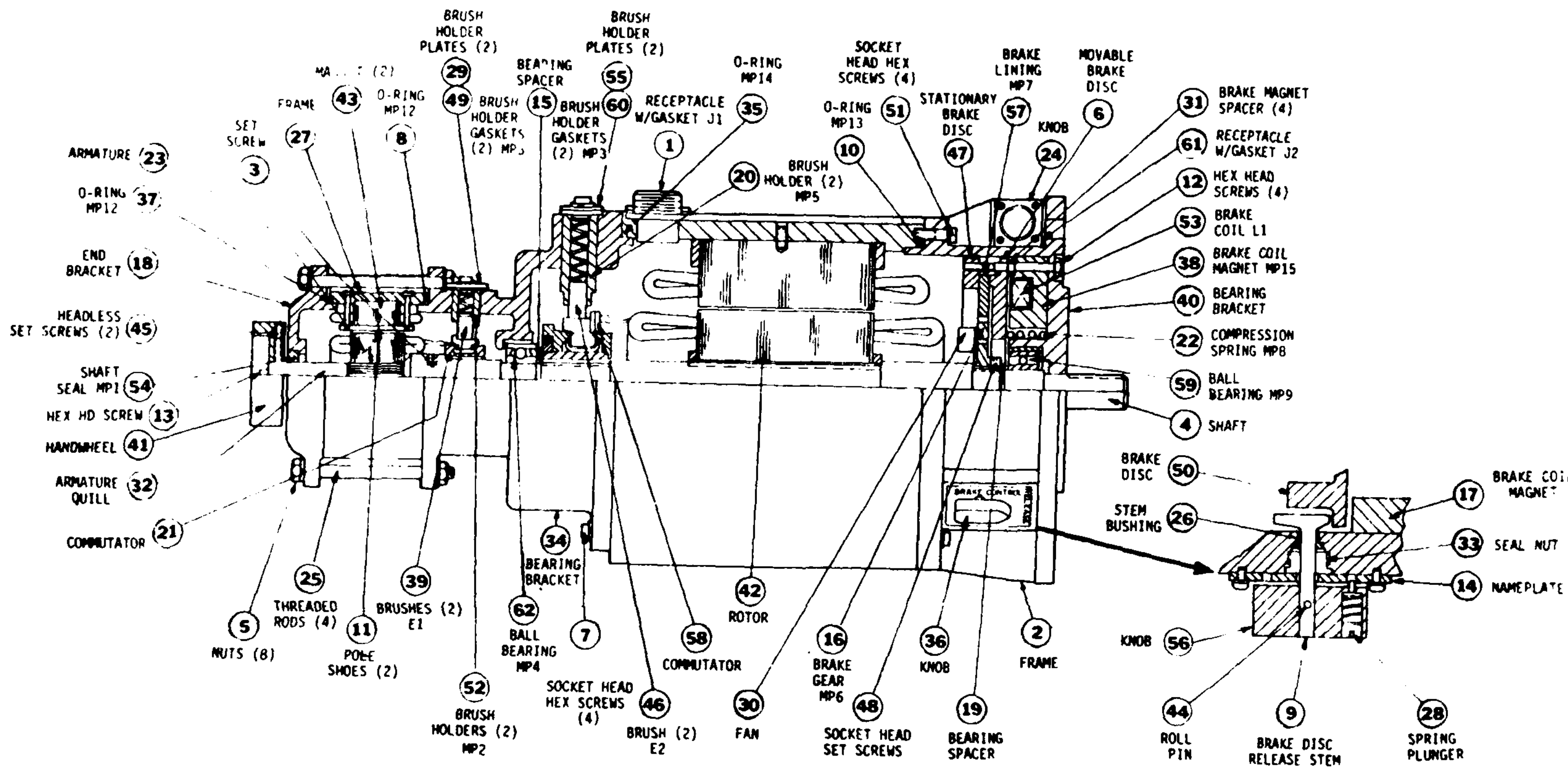
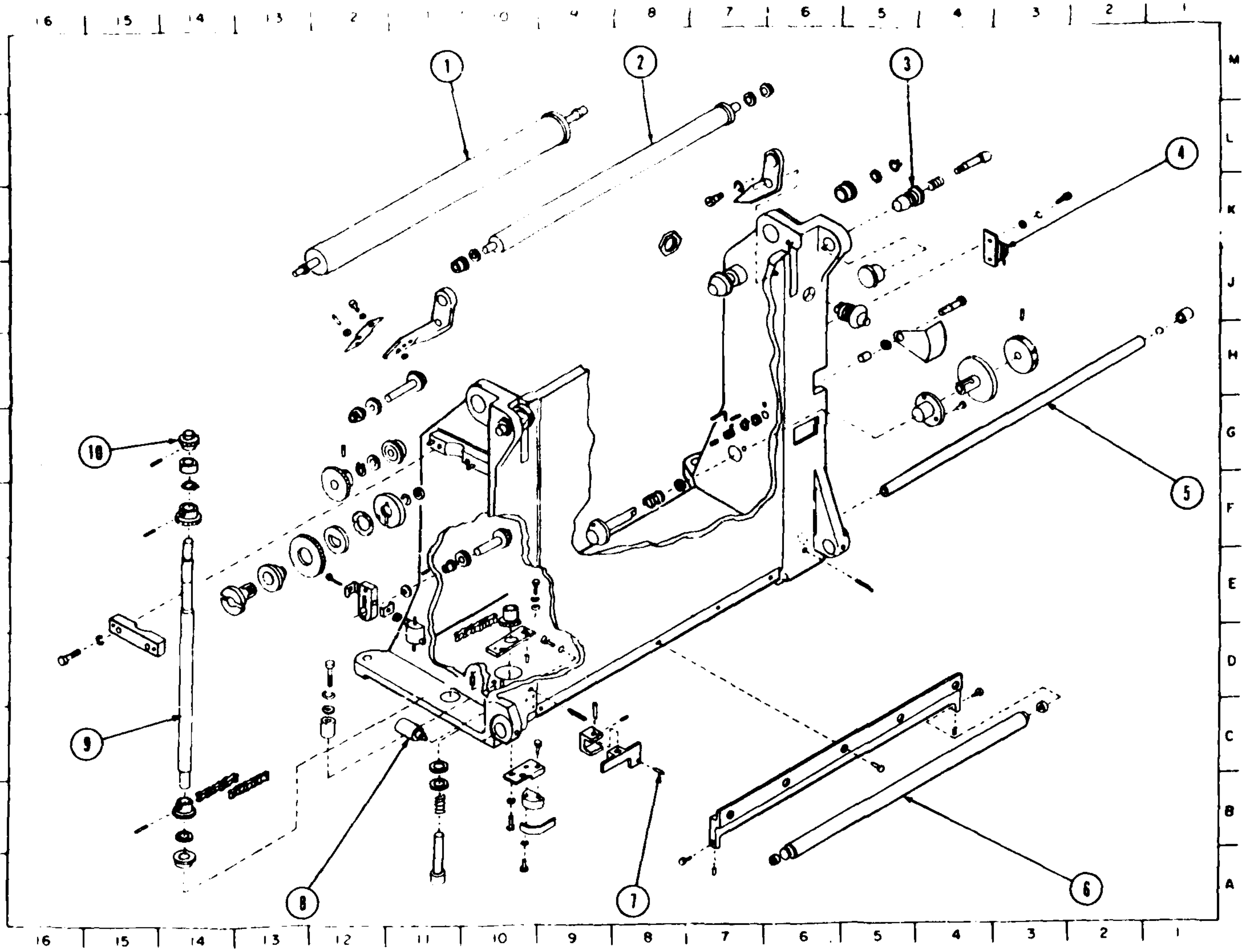


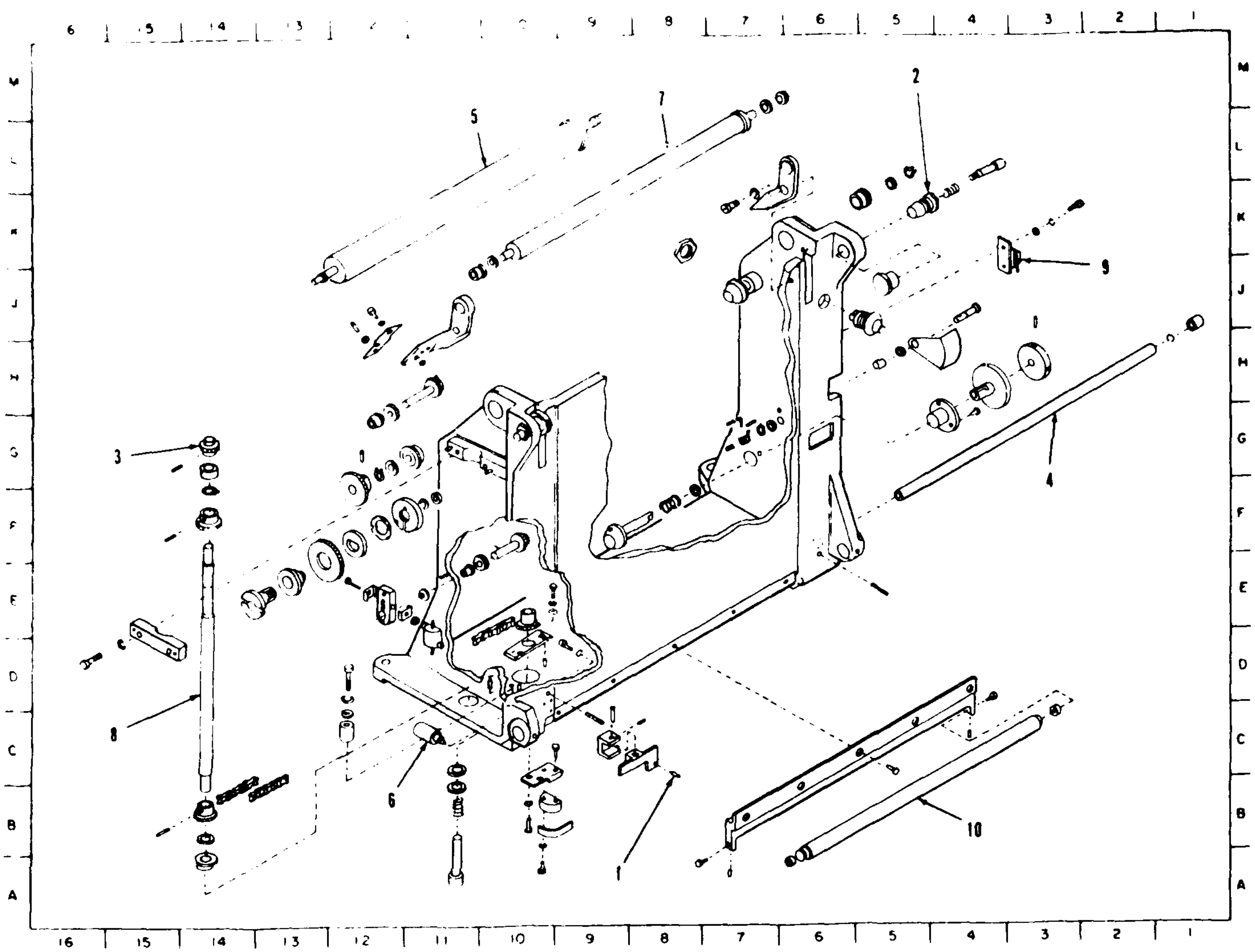
Figure A-2. Cross-sectional view, Case 4, Condition 5 (N/N-RAN).



Parts Location Index

CALLOUT NUMBER	REF DESIG	NAME
1	MP21	Output Roller
2	MP17	Leveling Roller
3	MP32	Adapter Plug
4	J2	Switch Assembly
5	MP7	Tension Roller
6	MP4	Printing Drum
7	MP2	Scriber
8	L1	Electrical Solenoid
9	MP27	Positive Shaft
10	MP23	Timing Gear

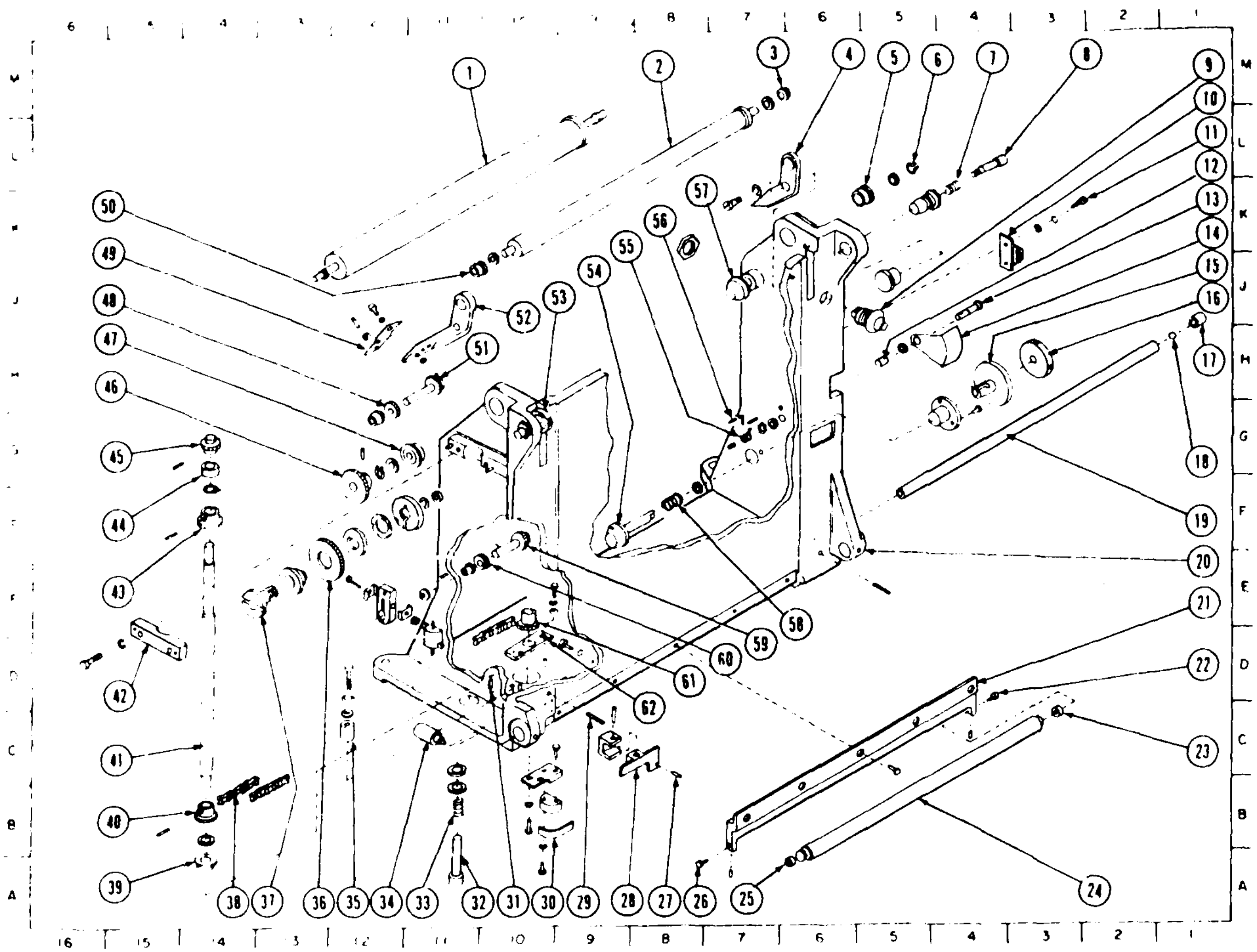
Figure A-3. Exploded view, Case 1, Condition 6 (SEQ/C/E).



Parts Location Index

CALLOUT NUMBER	REF DESIG	NAME
1	MP2	Scriber
2	MP32	Adapter Plug
3	MP23	Timing Gear
4	MP7	Tension Roller
5	MP21	Output Roller
6	L1	Electrical Solenoid
7	MP17	Leveling Roller
8	MP27	Positive Shaft
9	J2	Switch Assembly
10	MP4	Printing Drum

Figure A-4. Exploded view, Case 1, Condition 13 (RAN/NC/NE).

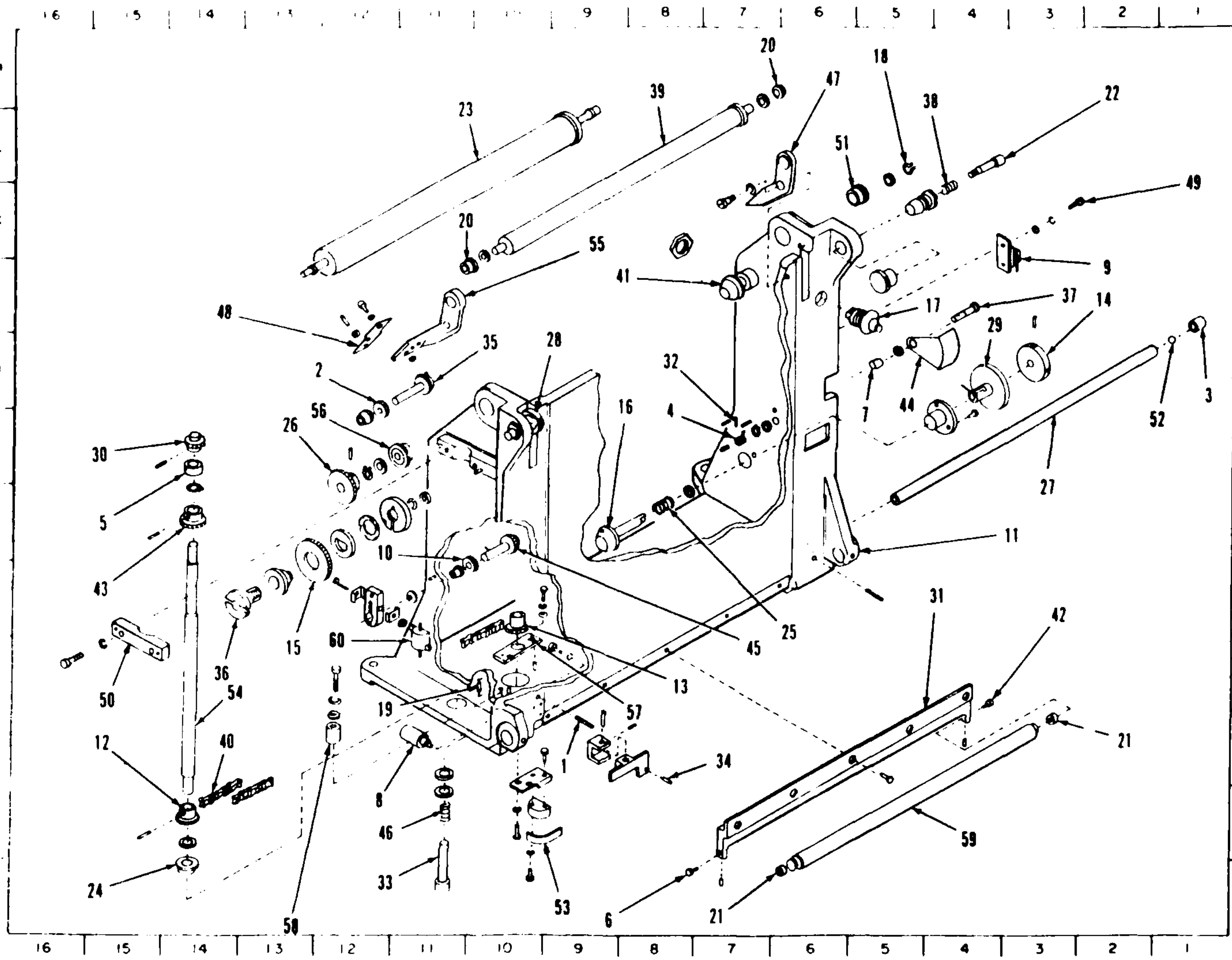


55	MP12	Tension Spring
56	MP11	Paper Measuring Device
57	MP55	Roller Mount
58	MP10	Compression Spring
59	MP33	Cap Assembly
60	MP38	Thrust Ball Bearing
61	MP34	Sprocket Wheel
62	MP37	Adjustment Bearing

Parts Location Index

CALLOUT NUMBER	REF DESIG	NAME
1	MP21	Output Roller
2	MP17	Leveling Roller
3	MP40	Bearing
4	MP41	Roller End Bracket
5	MP20	Flanged Ball Bearing
6	MP42	Stud Clip
7	MP16	Stud Spring
8	MP43	Shouldered Stud
9	S2	Pushbutton Switch
10	J2	Switch Assembly
11	MP44	Switch Bolt
12	MP15	Bearing
13	MP14	Shaft
14	MP13	Dial
15	MP9	Instruction Knob
16	MP[illegible]	Knob
17	MP5	Ball Adapter
18	MP6	Ball
19	MP7	Tension Roller
20	MP45	Roller End Bracket
21	MP46	Roller Mounting Plate
22	MP47	Set Screw
23	MP[illegible]	Annular Bearing
24	MP4	Printing Drum
25	MP[illegible]	Annular Bearing
26	MP[illegible]9	Set Screw
27	MP2	Scriber
28	MP40	Scriber Bracket
29	MP1	Spring
30	MP50	Corner Brace
31	R1	Resistor
32	MP36	Coupling
33	MP35	Spring
34	L1	Electrical Solenoid
35	MP51	Annular Bearing
36	MP3[illegible]	Hub Assembly Gear
37	MP27	Position Shaft
38	MP22	Block Chain
39	MP28	Flanged Ball Bearing
40	MP26	Sprocket Wheel
41	MP2[illegible]	Positive Shaft
42	MP52	Shaft Bracket
43	MP25	Gear
44	MP2[illegible]	Annular Bearing
45	MP2[illegible]	Timing Gear
46	MP19	Roller Shaft Gear
47	MP39	Flanged Ball Bearing
48	MP31	Thrust Ball Bearing
49	MP53	Bracket Plate
50	MP18	Flanged Ball Bearing
51	MP32	Hub Assembly Shaft
52	MP54	Oblique Roller Bracket
53	MP57	Roller Carriage
54	MP56	Knob Shaft

Figure A-5. Exploded view, Case 4, Condition 6 (SEQ/C/E).



Parts Location Index

CALLOUT NUMBER	REF DESIG	NAME
1	MP1	Spring
2	MP31	Thrust Ball Bearing
3	MP5	Ball Adapter
4	MP12	Tension Spring
5	MP24	Annular Bearing
6	MP49	Set Screw
7	MP15	Bearing
8	L1	Electrical Solenoid
9	J2	Switch Assembly
10	MP38	Thrustball Bearing
11	MP45	Roller End Bracket
12	MP26	Sprocket Wheel
13	MP34	Sprocket Wheel
14	MP8	Knob
15	MP30	Hub Assembly Gear
16	MP56	Knob Shaft
17	S2	Pushbutton Switch
18	MP42	Stud Clip
19	R1	Resistor
20	MP18	Flanged Ball Bearing
21	MP3	Annular Bearing
22	MP43	Shouldered Stud
23	MP21	Output Roller
24	MP28	Flanged Ball Bearing
25	MP10	Compression Spring
26	MP19	Roller Shaft Gear
27	MP7	Tension Roller
28	MP57	Roller Carriage
29	MP9	Instruction Knob
30	MP23	Timing Gear
31	MP46	Roller Mounting Plate
32	MP11	Paper Measuring Device
33	MP36	Coupling
34	MP2	Scriber
35	MP32	Hub Assembly Shaft
36	MP27	Position Shaft
37	MP14	Shaft
38	MP16	Stud Spring
39	MP17	Leveling Roller
40	MP22	Block Chain
41	MP55	Roller Mount
42	MP47	Set Screw
43	MP25	Gear
44	MP13	Dial
45	MP33	Cap Assembly
46	MP35	Spring
47	MP41	Roller End Bracket
48	MP53	Bracket Plate
49	MP44	Switch Bolt
50	MP52	Shaft Bracket
51	MP20	Flanged Ball Bearing
52	MP6	Ball
53	MP50	Corner Brace
54	MP29	Positive Shaft
55	MP54	Oblique Roller Bracket
56	MP39	Flanged Ball Bearing
57	MP37	Adjustment Bearing
58	MP51	Annular Bearing
59	MP4	Printing Drum
60	CR1	Semiconductor Device

Figure A-6. Exploded view, Case 4, Condition 13 (RAN/NC/NE)

Table B-1

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

CROSS-SECTIONAL VIEW: NUM-SEQ

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.30	0.30	0.70	0.90
Q1	1.15	1.00	1.25	1.70
Q2 (Median)	1.55	1.30	1.80	2.35
Q3	2.00	2.20	2.60	3.05
HI Score	3.60	3.20	3.60	6.50
HI-LO	3.30	2.90	2.90	5.60
Q3-Q1	0.85	1.20	1.35	1.35
N	36	36	36	36
Group	A	D	C	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 19.98$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-2

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

CROSS-SECTIONAL VIEW: NUM-RAN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.90	1.10	1.20
Q1	1.25	3.20	4.95	4.00
Q2 (Median)	2.00	3.80	7.75	6.50
Q3	2.70	4.80	15.60	9.00
HI Score	5.00	14.50	40.20	18.30
HI-LO	4.50	13.60	39.10	17.10
Q3-Q1	1.45	1.60	10.65	5.00
N	36	36	36	36
Group	B	A	D	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 69.26$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-3

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

CROSS-SECTIONAL VIEW: N/N-SEQ

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	0.70	1.10	0.60
Q1	1.20	1.65	2.35	2.00
Q2 (Median)	1.85	2.80	3.00	2.40
Q3	2.40	3.20	3.70	3.55
HI Score	5.60	5.40	9.20	9.30
HI-LO	4.60	4.70	8.10	8.70
Q3-Q1	1.20	1.55	1.35	1.55
N	36	36	36	36
Group	C	B	A	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 20.14$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-4

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

CROSS-SECTIONAL VIEW: N/N-RAN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.60	0.60	1.20
Q1	1.20	1.20	3.95	4.55
Q2 (Median)	2.00	2.10	6.00	8.25
Q3	2.80	3.55	8.65	10.95
HI Score	6.40	7.30	31.40	17.00
HI-LO	5.90	6.70	30.80	15.80
Q3-Q1	1.60	2.35	4.70	6.40
N	36	36	36	36
Group	D	C	B	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 65.72$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-5

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: SEQ/C/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	1.10	0.40	0.80
Q1	1.80	1.65	1.10	1.40
Q2 (Median)	2.00	2.30	1.25	2.00
Q3	2.65	3.10	1.65	2.75
HI Score	5.00	6.20	4.50	5.60
HI-LO	3.90	5.10	4.10	4.80
Q3-Q1	0.85	1.45	0.55	1.35
N	36	36	36	36
Group	A	D	C	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 31.1$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-6

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: SEQ/C/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.50	0.40	0.50
Q1	1.00	1.20	2.00	1.15
Q2 (Median)	1.20	1.90	3.85	1.60
Q3	2.00	3.00	5.70	2.35
HI Score	5.00	9.00	15.00	4.80
HI-LO	4.50	8.50	14.60	4.30
Q3-Q1	1.00	1.80	3.70	1.20
N	36	36	36	36
Group	B	A	D	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 32.2$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-7

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: SEQ/NC/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	1.60	1.20	0.70
Q1	1.80	2.30	2.25	1.20
Q2 (Median)	2.45	3.00	2.80	1.95
Q3	3.10	4.10	3.25	3.50
HI Score	6.90	8.60	5.80	8.00
HI-LO	6.00	7.00	4.60	7.30
Q3-Q1	1.30	1.80	1.00	2.30
N	36	36	36	36
Group	C	B	A	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 12.87$. Thus, $p < .01$, since $p = .01$ for $H > 11.34$.

Table B-8

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: SEQ/NC/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.60	1.00	0.90	0.50
Q1	1.30	2.00	1.20	2.60
Q2 (Median)	2.20	2.95	1.85	4.65
Q3	3.85	5.20	2.90	7.05
HI Score	9.00	26.20	7.10	12.50
HI-LO	8.40	25.20	6.20	12.00
Q3-Q1	2.55	3.20	1.70	4.45
N	36	36	36	36
Group	D	C	B	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 22.96$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-9

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: RAN/C/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	0.80	2.30	1.70
Q1	2.00	2.05	2.95	4.65
Q2 (Median)	2.20	3.40	3.95	8.55
Q3	2.95	6.25	5.05	16.10
HI Score	7.50	15.80	13.80	24.20
HI-LO	6.60	15.00	11.50	22.50
Q3-Q1	0.95	4.20	2.10	11.45
N	36	36	36	36
Group	D	C	B	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 48.43$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-10

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: RAN/C/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	1.00	2.40	0.60
Q1	1.80	2.35	5.50	6.25
Q2 (Median)	2.55	3.30	7.85	9.85
Q3	3.35	5.00	13.35	18.15
HI Score	6.00	7.60	51.20	52.20
HI-LO	5.10	6.60	48.80	51.60
Q3-Q1	1.55	2.65	7.85	11.90
N	36	36	36	36
Group	C	B	A	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. H = 74.36. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-11

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: RAN/NC/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	1.50	2.00	2.10
Q1	2.90	2.20	4.10	4.70
Q2 (Median)	4.15	3.20	6.95	6.40
Q3	5.55	4.60	12.95	10.95
HI Score	23.60	11.10	26.50	35.20
HI-LO	22.30	9.60	24.50	33.10
Q3-Q1	2.65	2.40	8.85	6.25
N	36	36	36	36
Group	B	A	D	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 31.16$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-12

Test Item Distribution Statistics

Task 1 (Point to Part Given Callout Number)

EXPLODED VIEW: RAN/NC/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.60	0.80	1.40	1.60
Q1	1.25	2.55	4.80	3.00
Q2 (Median)	1.85	4.85	9.20	6.00
Q3	2.80	8.35	11.20	10.70
HI Score	5.00	46.00	28.30	21.20
HI-LO	4.40	45.20	26.90	19.60
Q3-Q1	1.55	5.80	6.40	7.70
N	36	36	36	36
Group	A	D	C	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 52.18$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-13

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

CROSS-SECTIONAL VIEW: NOMEN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.90	1.40	1.60	1.20
Q1	1.10	3.90	2.95	4.75
Q2 (Median)	1.55	6.20	5.80	8.50
Q3	2.45	8.90	11.05	14.75
HI Score	6.50	19.50	36.30	40.30
HI-LO	5.60	18.10	34.70	39.10
Q3-Q1	1.35	5.00	8.10	10.00
N	36	36	36	36
Group	D	A	B	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 59.93$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-14

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

CROSS-SECTIONAL VIEW: NUM-SEQ

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.70	3.10	3.80	4.60
Q1	3.50	6.90	6.30	6.70
Q2 (Median)	4.65	8.20	9.05	8.70
Q3	5.00	11.45	10.55	11.05
HI Score	11.20	24.30	21.30	27.90
HI-LO	8.50	21.20	17.50	23.30
Q3-Q1	1.50	4.55	4.25	4.35
N	36	36	36	36
Group	B	C	D	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 56.94$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-15

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

CROSS-SECTIONAL VIEW: NUM-RAN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.10	2.90	5.50	5.90
Q1	3.80	9.05	12.20	12.70
Q2 (Median)	4.60	11.30	15.65	16.60
Q3	5.10	13.65	19.45	18.20
HI Score	8.30	26.20	32.00	41.20
HI-LO	6.20	23.30	26.50	35.30
Q3-Q1	1.30	4.60	7.25	5.50
N	36	36	36	36
Group	C	D	A	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 85.29$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-16

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

CROSS-SECTIONAL VIEW: N/N-SEQ

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	2.30	1.30	1.80
Q1	1.30	5.90	6.00	7.00
Q2 (Median)	2.30	8.05	10.25	13.25
Q3	3.00	11.90	15.15	17.05
HI Score	4.10	104.00	38.00	46.00
HI-LO	3.60	101.70	36.70	44.20
Q3-Q1	1.70	6.00	9.15	10.05
N	36	36	36	36
Group	D	A	B	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 70.92$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-17

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

CROSS-SECTIONAL VIEW: N/N-RAN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	0.90	1.50	2.50
Q1	1.45	3.25	3.50	6.85
Q2 (Median)	2.05	4.70	5.45	11.75
Q3	3.00	7.65	8.55	26.95
HI Score	4.20	14.30	21.00	63.10
HI-LO	3.20	13.40	19.50	60.60
Q3-Q1	1.55	4.40	5.05	20.10
N	36	36	36	36
Group	A	B	C	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 78.19$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-18

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: SEQ/C/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.70	2.90	2.00	5.10
Q1	3.60	4.00	4.20	8.90
Q2 (Median)	4.60	4.80	5.30	10.60
Q3	5.10	5.90	7.45	13.25
HI Score	8.90	13.10	18.50	58.00
HI-LO	6.20	10.20	16.50	52.90
Q3-Q1	1.50	1.90	3.25	4.35
N	36	36	36	36
Group	B	A	D	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 66.89$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-19

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: SEQ/C/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	4.60	4.00	3.60
Q1	2.25	6.10	6.90	9.80
Q2 (Median)	3.15	8.20	8.80	15.15
Q3	4.00	10.05	11.65	17.50
HI Score	5.00	33.10	20.20	52.20
HI-LO	3.70	28.50	16.20	48.60
Q3-Q1	1.75	3.95	4.75	7.70
N	36	36	36	36
Group	C	B	A	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 86.85$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-20

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: SEQ/NC/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.80	4.10	3.60	2.20
Q1	4.15	6.10	5.45	4.75
Q2 (Median)	4.75	8.00	10.80	6.90
Q3	6.05	10.20	15.20	9.65
HI Score	9.10	19.60	23.00	23.20
HI-LO	7.30	15.50	19.40	21.00
Q3-Q1	1.90	4.10	9.75	4.90
N	36	36	36	36
Group	D	C	B	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 30.28$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-21

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: SEQ/NC/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.70	3.00	2.00	5.20
Q1	3.00	5.25	2.90	10.20
Q2 (Median)	4.00	7.65	3.50	13.95
Q3	5.30	12.15	4.70	21.30
HI Score	19.90	24.80	18.00	35.60
HI-LO	18.20	21.80	16.00	30.40
Q3-Q1	2.30	6.90	1.80	11.10
N	36	36	36	36
Group	A	D	C	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 80.45$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-22

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: RAN/C/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	2.00	3.30	3.20	5.80
Q1	4.30	7.95	11.50	12.95
Q2 (Median)	5.20	10.60	15.70	15.80
Q3	5.95	12.75	23.20	20.95
HI Score	8.70	23.00	36.00	35.20
HI-LO	6.70	19.70	32.80	29.40
Q3-Q1	1.65	4.80	11.70	8.00
N	36	36	36	36
Group	A	D	C	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 84.09$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-23

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: RAN/C/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	3.60	5.90	4.40
Q1	3.65	7.10	11.20	10.30
Q2 (Median)	4.90	8.55	17.55	13.40
Q3	6.05	10.25	23.70	16.40
HI Score	11.00	33.30	64.00	31.10
HI-LO	9.70	29.70	58.10	26.70
Q3-Q1	2.40	3.15	12.50	6.10
N	36	36	36	36
Group	D	C	B	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 82.01$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-24

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: RAN/NC/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	3.60	4.60	7.60	8.70
Q1	5.00	7.00	17.95	17.40
Q2 (Median)	5.90	10.65	27.20	21.15
Q3	7.60	13.65	34.50	33.40
HI Score	29.00	45.20	82.80	66.00
HI-LO	25.40	40.60	75.20	57.30
Q3-Q1	2.60	6.65	16.55	16.00
N	36	36	36	36
Group	C	B	A	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 83.84$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-25

Test Item Distribution Statistics

Task 2 (Point to Part Given Nomenclature)

EXPLODED VIEW: RAN/NC/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	3.60	7.60	5.20
Q1	2.30	6.35	12.65	11.25
Q2 (Median)	3.20	8.30	15.90	19.90
Q3	4.60	11.35	20.60	33.65
HI Score	8.70	15.30	35.20	59.80
HI-LO	7.40	11.70	27.60	54.60
Q3-Q1	2.30	5.00	7.95	22.40
N	36	36	36	36
Group	B	A	D	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 94.78$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-26

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

CROSS-SECTIONAL VIEW: NOMEN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.50	0.80	0.80	1.00
Q1	0.80	1.20	2.00	1.70
Q2 (Median)	1.20	1.30	2.25	2.00
Q3	1.50	1.95	3.00	2.60
HI Score	2.20	3.60	8.10	11.10
HI-LO	1.70	2.80	7.30	10.10
Q3-Q1	0.70	0.75	1.00	0.90
N	36	36	36	36
Group	B	C	D	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 53.94$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-27

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

CROSS-SECTIONAL VIEW: NUM-SEQ

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.10	2.30	2.00	4.00
Q1	1.80	3.65	3.00	5.30
Q2 (Median)	2.15	5.00	3.35	6.05
Q3	3.00	7.60	4.25	7.25
HI Score	6.00	15.70	6.60	13.00
HI-LO	4.90	13.40	4.60	9.00
Q3-Q1	1.20	3.95	1.25	1.95
N	36	36	36	36
Group	C	D	A	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 89.34$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-28

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

CROSS-SECTIONAL VIEW: NUM-RAN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	2.80	1.80	2.70
Q1	2.00	3.80	2.80	4.90
Q2 (Median)	2.20	4.60	3.70	5.75
Q3	2.80	5.20	4.45	7.05
HI Score	3.80	7.00	6.20	10.20
HI-LO	2.50	4.20	4.40	7.50
Q3-Q1	0.80	1.40	1.65	2.15
N	36	36	36	36
Group	D	A	B	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 84.07$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-29

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

CROSS-SECTIONAL VIEW: N/N-SEQ

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.00	0.80	0.50	1.00
Q1	1.50	1.45	1.35	1.70
Q2 (Median)	2.00	1.80	2.00	2.05
Q3	2.20	2.60	2.60	2.65
HI Score	4.00	4.80	11.10	3.60
HI-LO	3.00	4.00	10.60	2.60
Q3-Q1	0.70	1.15	1.25	0.95
N	36	36	36	36
Group	A	B	C	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 2.4$. Thus, $p > .05$, since $p = .05$ for $H > 7.82$.

Table B-30

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

CROSS-SECTIONAL VIEW: N/N-RAN

Statistic	Number of Callouts			
	10	27	44	62
LO Score	0.80	0.80	1.00	1.70
Q1	1.90	1.20	2.05	2.85
Q2 (Median)	2.30	1.85	2.75	3.65
Q3	2.95	2.40	4.25	4.50
HI Score	8.60	4.00	12.70	12.00
HI-LO	7.80	3.20	11.70	10.30
Q3-Q1	1.05	1.20	2.20	1.65
N	36	36	36	36
Group	B	C	D	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 37.45$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-31

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: SEQ/C/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.40	1.70	2.10	3.00
Q1	2.05	3.05	3.10	4.00
Q2 (Median)	2.60	3.60	3.20	4.35
Q3	3.00	4.25	4.00	5.05
HI Score	3.80	10.00	10.70	9.70
HI-LO	2.40	8.30	8.60	6.70
Q3-Q1	0.95	1.20	0.90	1.05
N	36	36	36	36
Group	C	B	A	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 69.68$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-32

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: SEQ/C/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.60	1.80	2.00	2.20
Q1	2.25	2.15	2.80	3.55
Q2 (Median)	2.95	2.45	3.20	3.90
Q3	3.60	3.00	3.60	4.30
HI Score	5.00	3.80	4.10	6.00
HI-LO	3.40	2.00	2.10	3.80
Q3-Q1	1.35	0.85	0.80	0.75
N	36	36	36	36
Group	D	C	B	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 49.59$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-33

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: SEQ/NC/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.60	2.00	2.00	2.60
Q1	2.70	3.05	2.30	3.40
Q2 (Median)	3.00	3.65	3.00	4.00
Q3	3.20	4.00	3.30	4.50
HI Score	4.60	5.00	4.90	10.50
HI-LO	3.00	3.00	2.90	7.90
Q3-Q1	0.50	0.95	1.00	1.10
N	36	36	36	36
Group	A	D	C	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 41.64$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-34

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: SEQ/NC/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.50	2.30	1.80	1.80
Q1	2.15	3.20	3.10	2.60
Q2 (Median)	2.85	3.85	3.60	3.00
Q3	3.20	4.90	4.10	3.45
HI Score	4.80	7.90	5.50	7.10
HI-LO	3.30	5.60	3.70	5.30
Q3-Q1	1.05	1.70	1.00	0.85
N	36	36	36	36
Group	B	A	D	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 35.31$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-35

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: RAN/C/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	2.50	2.20	2.40
Q1	1.85	3.20	3.10	3.45
Q2 (Median)	2.20	3.85	3.65	4.05
Q3	2.80	4.00	4.15	4.55
HI Score	3.20	5.80	5.60	11.50
HI-LO	1.90	3.30	3.40	9.10
Q3-Q1	0.95	0.80	1.05	1.10
N	36	36	36	36
Group	B	A	D	C

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 68.95$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-36

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: RAN/C/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.70	2.00	1.80	1.70
Q1	2.00	2.50	3.00	3.05
Q2 (Median)	2.45	3.00	3.75	3.60
Q3	3.00	3.20	4.10	4.25
HI Score	5.00	10.10	5.30	7.20
HI-LO	3.30	8.10	3.50	5.50
Q3-Q1	1.00	0.70	1.10	1.20
N	36	36	36	36
Group	A	D	C	B

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 40.36$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-37

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: RAN/NC/E

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.30	1.30	2.30	2.50
Q1	1.80	2.60	2.55	3.60
Q2 (Median)	2.15	3.00	3.65	4.00
Q3	2.80	3.60	4.00	4.55
HI Score	4.00	4.90	5.60	6.00
HI-LO	2.70	3.60	3.30	3.50
Q3-Q1	1.00	1.00	1.45	0.95
N	36	36	36	36
Group	D	C	B	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 63.6$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

Table B-38

Test Item Distribution Statistics

Task 3 (Tell Nomenclature of Marked Part)

EXPLODED VIEW: RAN/NC/NE

Statistic	Number of Callouts			
	10	27	44	62
LO Score	1.80	1.20	1.80	2.20
Q1	2.10	2.00	2.20	2.55
Q2 (Median)	2.85	2.50	2.90	3.10
Q3	3.55	3.15	3.45	3.90
HI Score	7.00	4.60	6.40	13.70
HI-LO	5.20	3.40	4.60	11.50
Q3-Q1	1.45	1.15	1.25	1.35
N	36	36	36	36
Group	C	B	A	D

<u>Note</u>. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 12.47$. Thus, $p < .01$, since $p = .01$ for $H > 11.34$.

Table B-39

Test Item Distribution Statistics

Task 4 (Use Zone System to Point to Part Given Callout Number)

Exploded View with 62 Callouts

Statistic	RAN/C/E	RAN/C/NE	RAN/NC/E	RAN/NC/NE
LO Score	5.10	5.50	2.70	6.50
Q1	9.45	9.05	9.35	8.40
Q2 (Median)	11.90	12.15	12.60	11.16
Q3	18.90	16.50	16.60	12.50
HI Score	39.20	23.80	44.10	37.60
HI-LO	34.10	18.30	41.40	31.10
Q3-Q1	9.45	7.45	7.25	4.10
N	36	36	36	36
Group	A	B	C	D

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 5.07$. Thus, $p > .05$, since $p = .05$ for $H > 7.82$.

Table B-40

Test Item Distribution Statistics

Task 5 (Use Zone System to Point to Part Given Nomenclature)

Exploded View with 62 Callouts

Statistic	RAN/C/E	RAN/C/NE	RAN/NC/E	RAN/NC/NE
LO Score	7.00	8.60	12.80	14.80
Q1	12.80	15.90	19.20	22.55
Q2 (Median)	16.70	25.45	24.30	27.15
Q3	22.50	29.40	31.00	34.25
HI Score	61.80	56.40	92.30	73.60
HI-LO	54.80	47.80	79.50	58.80
Q3-Q1	9.70	13.50	11.80	11.70
N	36	36	36	36
Group	D	C	B	A

Note. Kruskal-Wallis k-sample test of distribution differences yields H, which is distributed as Chi-square with k-1 degrees of freedom. $H = 25.06$. Thus, $p < .001$, since $p = .001$ for $H > 16.27$.

DTIC

END

4-86